Scale and Hydrogeologic Complexity in Models of Ground-Water Flow for Newark-Basin Aquifers

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U.S. Geological Survey

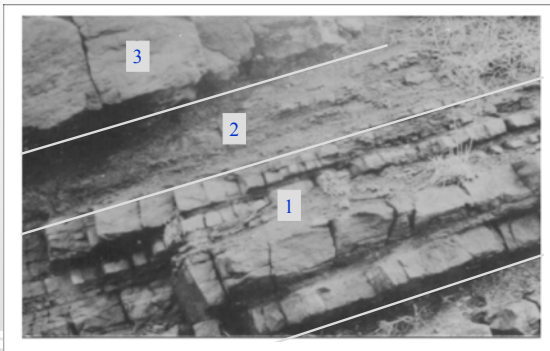
Recent Quantitative Studies in Newark Basin

- Regional Aquifer Studies (USGS)
- Penn. & NJ Superfund Sites (EPA, DEP)
- NAWC West Trenton (U.S. Navy)
- Rutgers Golf Course, Piscataway Twp.

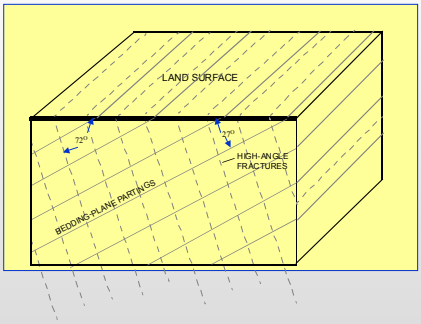
Investigations

- Geophysical logging
- Water-level maps and monitoring
- Aquifer tests: multi-well and single-well packer tests
- Ground-water flow and contaminant transport simulations

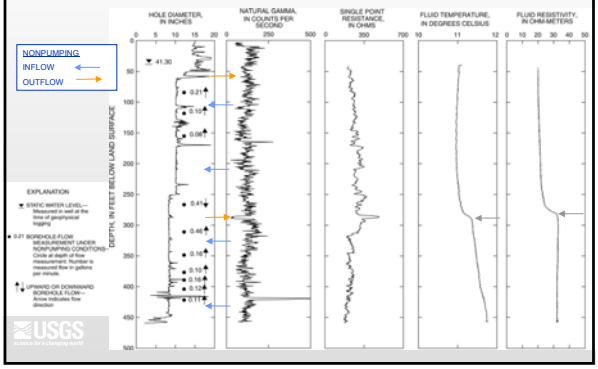
DIPPING GEOLOGIC UNITS



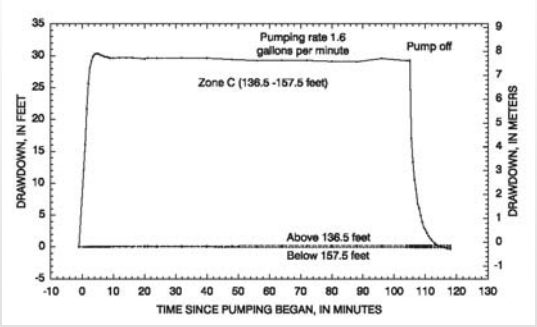
Highly Heterogeneous



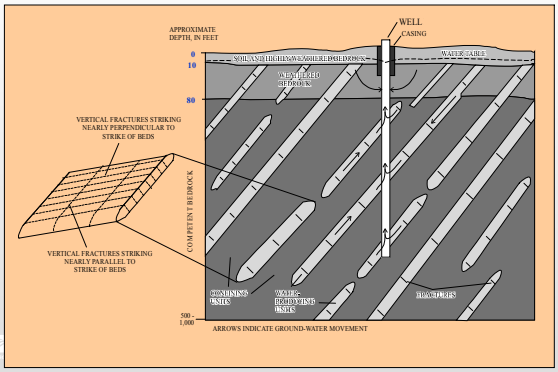
Logs for well Mg-68



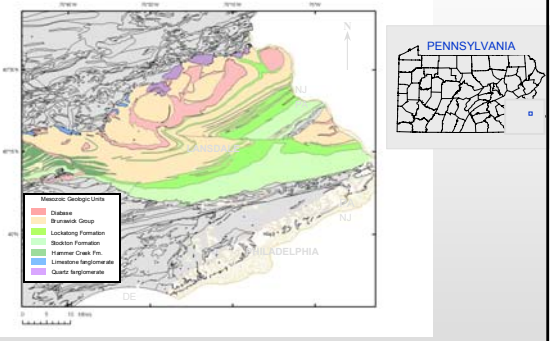
Packer Test in Open Borehole



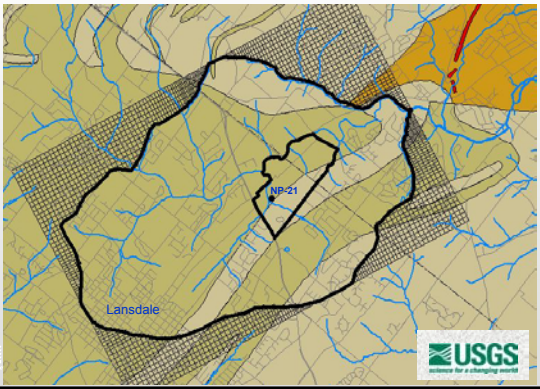
CONCEPTUAL MODEL OF DIPPING BEDS



NEWARK BASIN, SOUTHEASTERN PENNYLVANIA



NORTH PENN 5 SUPERFUND SITE
Geology and Modeled Area



Structure in GW Model

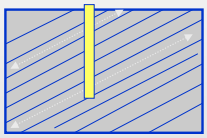
- Slug Test – Homogeneous
- Packer Test – Homogeneous Layers
- Aquifer Test – Homogeneous, Layers, Anisotropy, Simple Structure (Wedge)

Scale & Complexity of GW Models

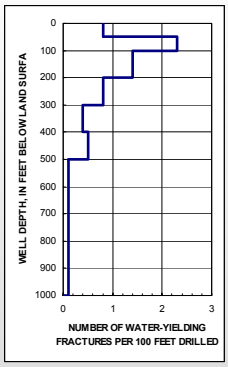
- Site Flow Model – Heterogeneous, Multi-layer, w/ Structure
  - Dipping Beds as Stair Step
  - Dipping Layers as Model Layers
- Regional – Anisotropy, Fewer Layers, More Homogeneous

REGIONAL MODEL STRUCTURE

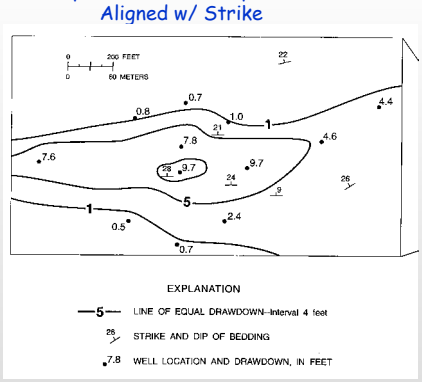
Aquifer System



Model Layers



Anisotropic Drawdown in Open Boreholes Aligned w/ Strike



REGIONAL GROUND-WATER-FLOW MODEL GRID

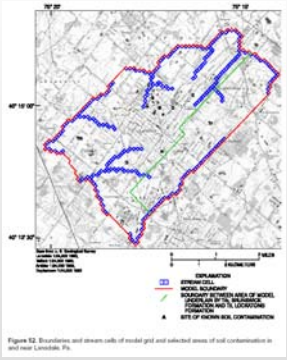
Major Axes Aligned with Regional Strike & Dip

Calibrated to Synoptic Water Levels & Streamflow, Average Pumping

Anisotropy about 10:1

Max T about 3,000 ft²/d

K – Brunswick > Lockatong > Weathered (Saprolite)



Local-Scale Model Areas within Regional-Scale Model

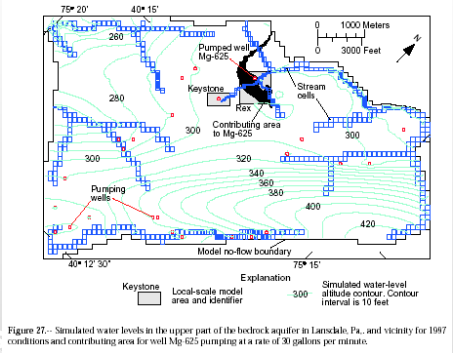


Figure 27.– Simulated water levels in the upper part of the bedrock aquifer in Lansdale, Pa., and vicinity for 1987 conditions and contributing area for well Mg-625 pumping at a rate of 30 gallons per minute.

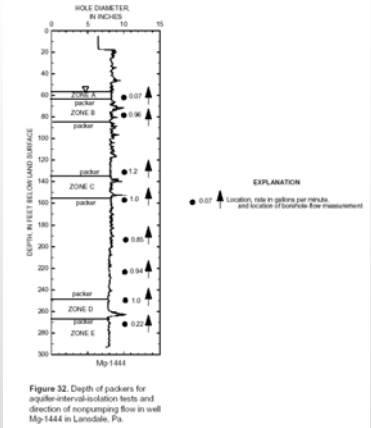
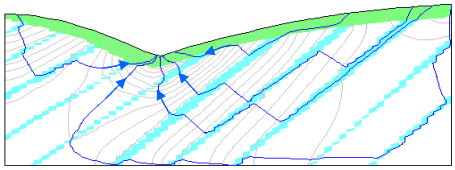
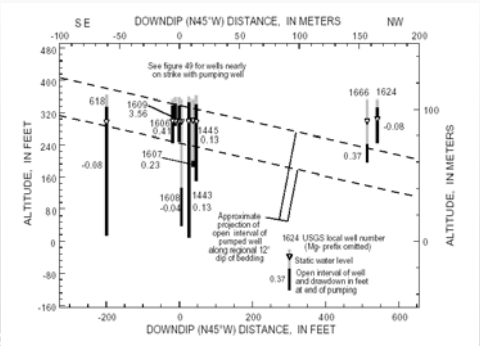


Figure 32. Depth of packers for aquifer-interval-isolation tests and direction of nonpumping flow in well Mg-1444 in Lansdale, Pa.

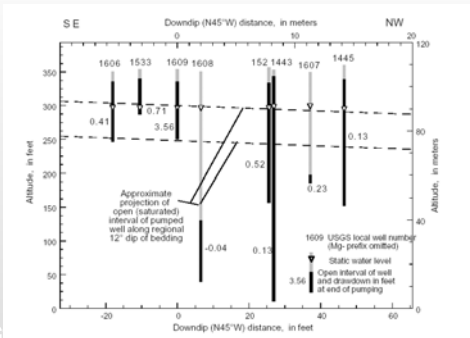
Hydraulic Head Distribution and Ground-water Flow Paths



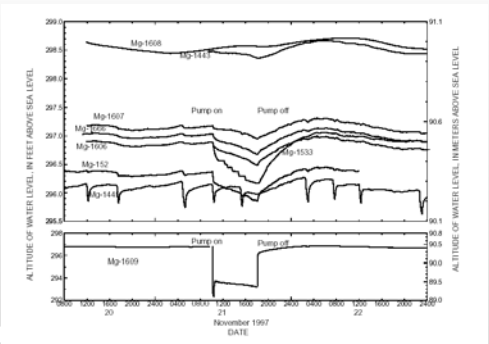
Open Zones and Drawdown



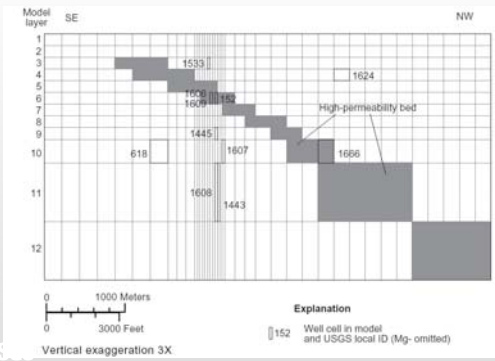
Open Zones and Drawdown



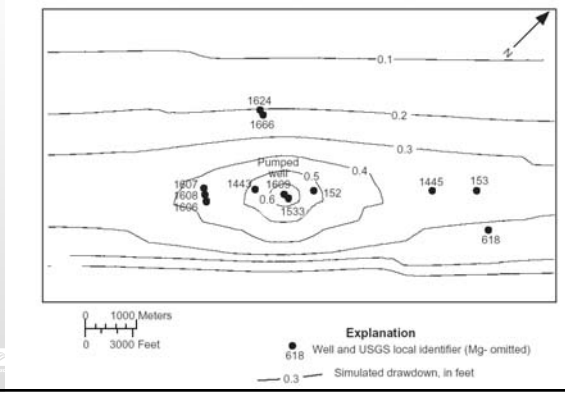
Water Levels



Model Cross-Section



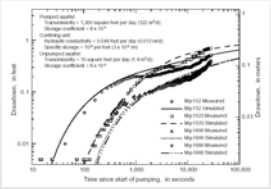
Simulated Drawdown at Depth of Pumping

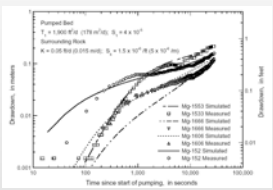


Aquifer Test Analysis

Analytical – Neuman 2 Aquifer

Numerical – Stairstep Dipping Aquifer





Aquifer Test Analysis

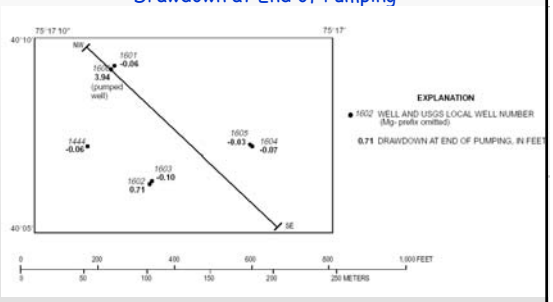
Numerical – Stairstep Dipping Aquifer

Table 3.– Optimum and approximate, individual, 95-percent confidence-interval values for hydraulic conductivity and specific storage for calibrated simulation of ground-water flow at the John Evans and Sons property in north-central Lansdale, Pa.
[ft²/d, feet squared per day; ft/d, foot per day]

Parameter	Units	Optimum value	Approximate, individual, 95-percent confidence interval	
			Lower value	Upper value
Pumped bed transmissivity	ft²/d	1,900	500	2,300
Bulk rock hydraulic conductivity	ft/d	0.05	.033	.077
Pumped bed storage coefficient	-	4.0×10^{-5}	2.3×10^{-5}	7.0×10^{-5}
Bulk rock specific storage	per foot	1.5×10^{-6}	9.9×10^{-7}	2.3×10^{-6}

Dipping Layers Model

Drawdown at End of Pumping



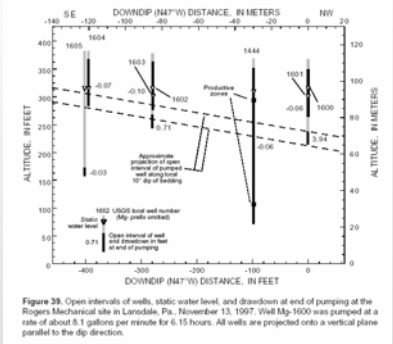


Figure 39. Open intervals of wells, static water level, and drawdown at end of pumping at the Rogers Mechanical site in Lansdale, Pa., November 13, 1997. Well Mg-1600 was pumped at a rate of about 8.1 gallons per minute for 6.15 hours. All wells are projected onto a vertical plane parallel to the dip direction.

Dipping Layers Model

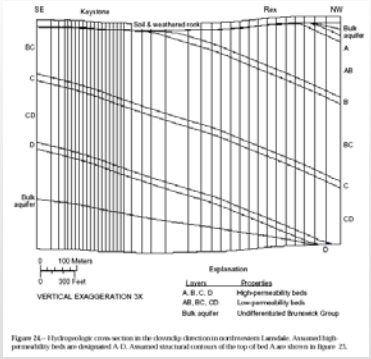
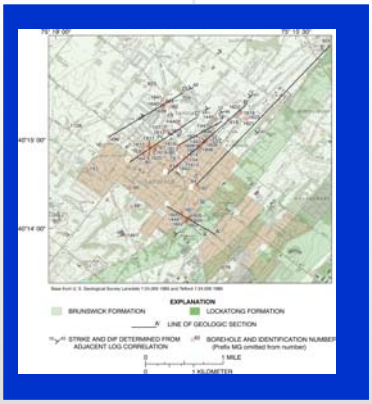


Figure 24.– Hydrogeologic cross section in the dowdip direction in northwestern Lansdale. Assumed high-permeability beds are designated A-D. Assumed structural contours of the top of bed A are shown in figure 23.

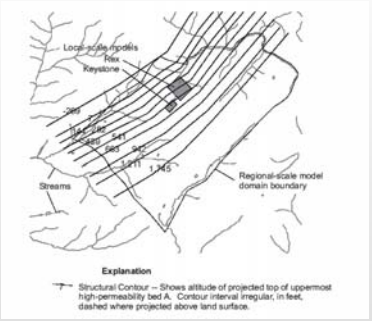
Bed orientation determined from log correlation

Strike: N.40-62° E.

Dip: N.8-12° W.



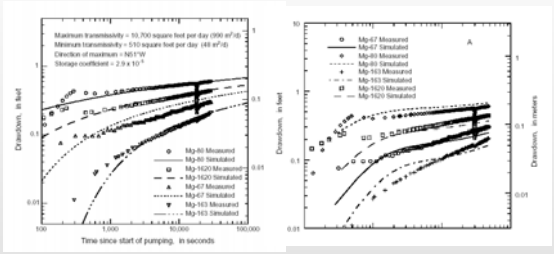
Dipping Layers – 2 Aquifer Tests



Aquifer Test Analysis

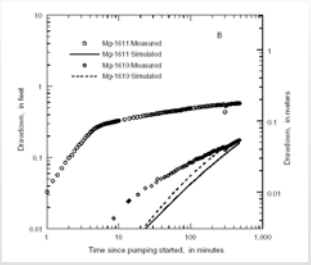
Analytical – Anisotropic

Numerical – Dipping Layers



Aquifer Test Analysis

Numerical –Dipping Layers



Parameters Calibrated

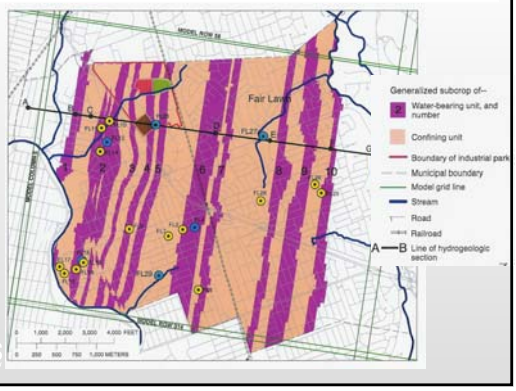
Table 4.-- Optimum and approximate, individual, 95-percent confidence-interval values for hydraulic conductivity and specific storage for calibrated simulation of ground-water flow in northwestern Lansdale, Pa.

[ft/d, foot per day; ft²/d; feet squared per day]

Parameter	Units	Optimum value	Approximate, individual, 95-percent confidence interval	
			Lower value	Upper value
Beds A & B hydraulic conductivity	ft/d	7.2	5.7	9.2
Beds A & B transmissivity[1]	ft²/d	142	112	181
Beds C & D hydraulic conductivity	ft/d	36	15	82
Beds C & D transmissivity[1]	ft²/d	709	295	1,610
Interbeds AB & BC hydraulic conductivity	ft/d	9.6×10^{-4}	1.5×10^{-4}	5.4×10^{-3}
Interbed CD hydraulic conductivity	ft/d	.26	.087	.78
Beds A & B specific storage	per foot	1.2×10^{-6}	9.3×10^{-7}	1.5×10^{-6}
Beds C & D specific storage	per foot	1.4×10^{-6}	1.4×10^{-7}	1.3×10^{-5}
Interbeds AB & BC specific storage	per foot	9.9×10^{-8}	1.8×10^{-8}	5.6×10^{-7}
Interbed CD specific storage	per foot	4.2×10^{-6}	6.4×10^{-7}	2.8×10^{-5}

[1] Transmissivity is product of hydraulic conductivity and bed thickness [19.7 ft (6 m)].

Bergen County, NJ



Packer Testing – High-K Water-Bearing Zones

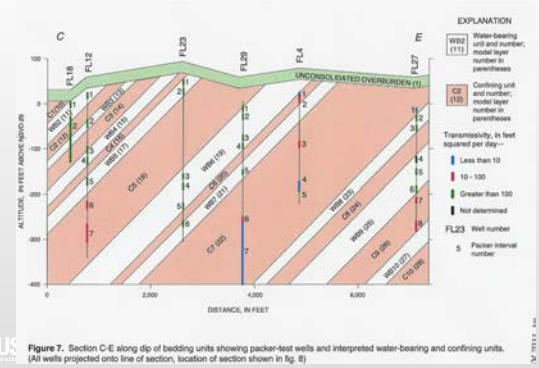
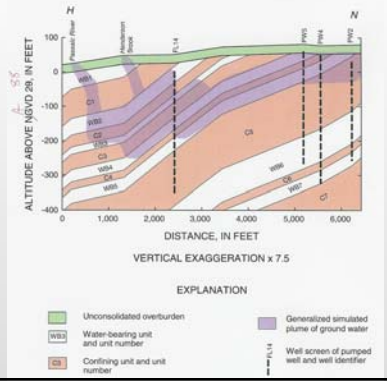
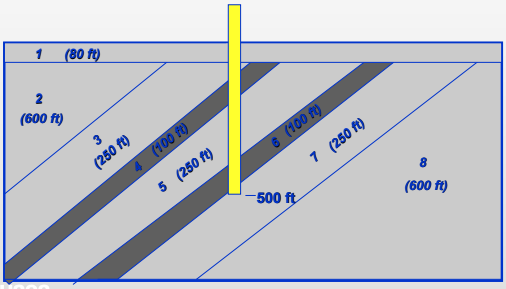


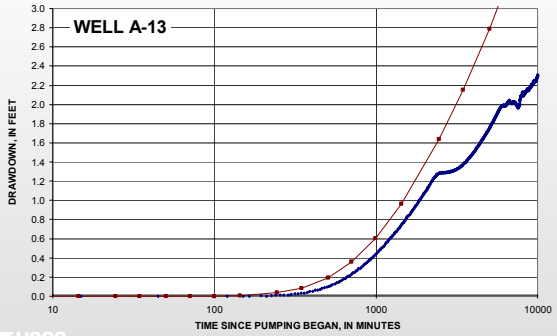
Figure 7. Section C-E along dip of bedding units showing packer-test wells and interpreted water-bearing and confining units. (All wells projected onto line of section, location of section shown in fig. 8)

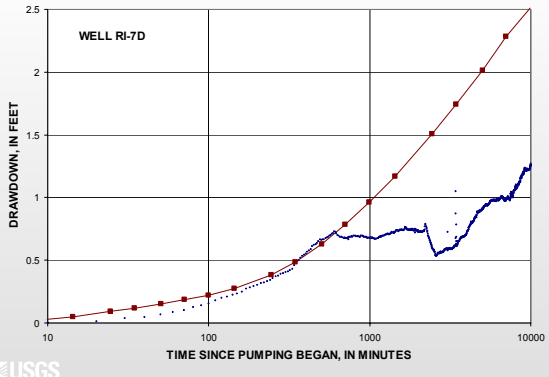
Generalized Plume Cross-Section

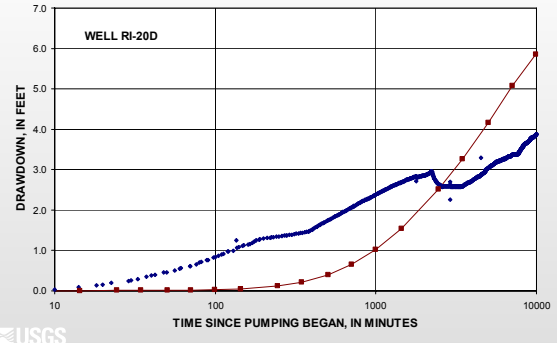


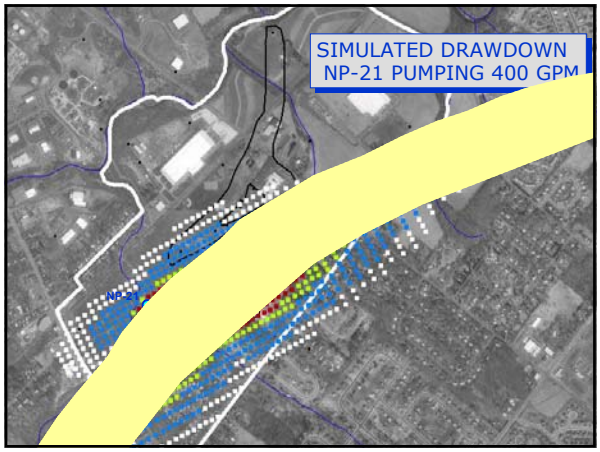
Aquifer Test, 1 week at 250 gpm

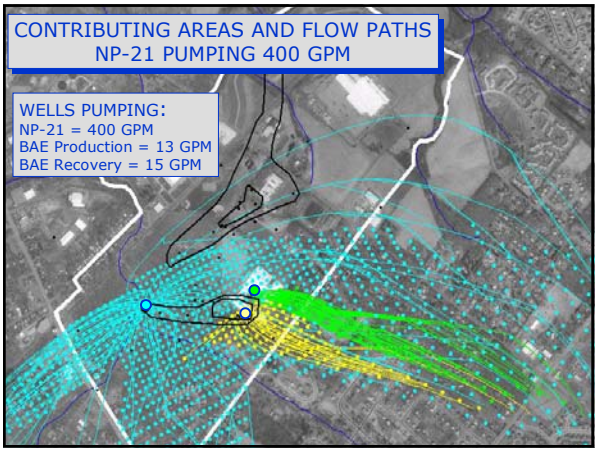




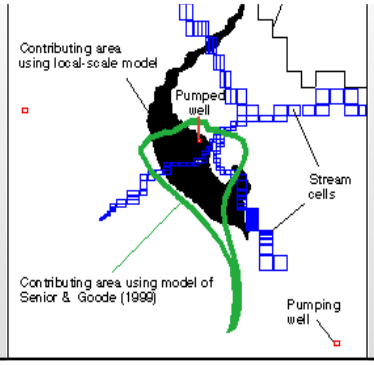








COMPARISON OF CAPTURE AREAS FROM REGIONAL MODEL AND LOCAL-SCALE MODEL



USGS

Structure in GW Model - NOW

- 2D Single Layer, Anisotropy – No Longer Used
- Multi-Layer, Anisotropy – Still Useful for Regional Simulation
- Dipping Beds as Stair Step – No Longer Used
- Dipping Layers as Model Layers – Most Realistic, used for Site Scale
- Driven by Measurements, including Contaminants & Tracers

USGS

Structure in GW Model - SOON

- Dipping Layers
- Zonation within High-K and Low-K Beds, Faults
- Embedding of Site Models in Regional Models
- Common Calibration Approach for Field Tests and Regional Flow

USGS

Detailed Hydrogeologic Framework, NAWC West Trenton

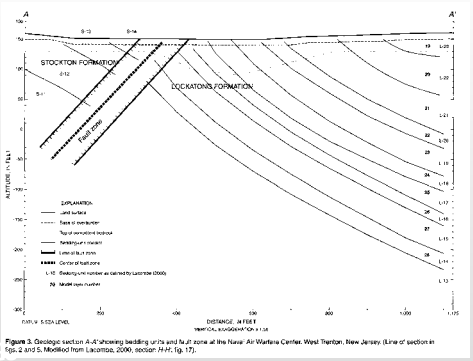


Figure 3. Geologic section A-A' showing bedding units and fault zone at the Naval Air Warfare Center, West Trenton, New Jersey. (Line of section in figs. 2 and 5. Modified from Lacombe, 2000, section A-A', fig. 17).

USGS